

ORBITAL PHASE DEPENDENT IUE SPECTRA OF THE NOVA-LIKE BINARY TT ARIETIS

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ABSTRACT

We have obtained nine low-dispersion IUE spectra of the nova-like binary TT Ari over its $3^{\text{h}}17^{\text{m}}$ orbital period. Four short-wave spectra and five long-wave spectra exhibit marked changes in line strength and continuum shape with orbital phase. The short wave spectra show the presence, in absorption, of C III, Lyman α , Si III, NV, Si IV, CIV, He II, Al III, and N IV. CIV shows a P Cygni profile on two of the spectra. Implications of these spectra for the nature of nova-like variables will be discussed.

INTRODUCTION

The nova-like variable TT Ari (=BD + 14°341) was shown (ref. 1) to be a single line spectroscopic binary with orbital period $P = 0.13755$ days whose observed spectroscopic and photometric properties could be accounted for with the canonical model for cataclysmic variables; a low-mass red star losing mass through Roche lobe overflow to a disk surrounding a white dwarf primary. At the point of impact of the gas stream with the accretion disk, a hot spot is produced which also contributes to the light from the system.

Photometric studies have been reported (ref. 2, 3, 4) which show quasi-sinusoidal light variations with photometric period $P_{\Delta} = 0.1328$ days having an amplitude $\approx 0^{\text{m}}.2$ and quasi-periodic light variations with periods of $\approx 800^{\text{s}}$ and $\approx 40^{\text{s}}$ having amplitudes $0^{\text{m}}.1$ to $0^{\text{m}}.2$. Long term light variability ranging from $9^{\text{m}}.5$ to $11^{\text{m}}.8$ over a time interval of about a century are apparent from comparison with those magnitudes given in the BD catalogue to the value listed by Kukarkin et al. (ref. 5).

TT Ari has been observed as an X-ray source (ref. 6) by the Einstein satellite in the energy range 0.15 to 4.5 Kev. We report below on IUE spectra of TT Ari as a function of orbital phase which we have obtained as part of a survey of nova-like variables at ultraviolet wavelengths.

OBSERVATIONS

We have observed TT Ari through its orbit with the IUE satellite at low dispersion, both short and long wavelength spectra (1100Å to 3200Å). Table 1 lists the camera image number, aperture size, exposure time and time of mid-exposure expressed in universal time.

We have displayed the four short-wave spectra in figures 1-4. Absorption line features are present due to C III ($\lambda 1175$), Ly α + He II ($\lambda 1216$), NV ($\lambda 1240$), OI + Si III ($\lambda 1300$), Si III ($\lambda 1394$), C IV ($\lambda 1550$), He II ($\lambda 1640$) and Al III ($\lambda 1850$). In SWP 6276 and SWP 6277 the Al III feature is not present. The long-wave spectra reveal few features that can be reliably considered real due to the noise level present. Not surprisingly, the contribution of the secondary star to the long-wave spectrum is not apparent, a fact in agreement with the optical spectra. We place an upper limit on the reddening $E(B-V) \sim 0.1$, based upon the lack of a detectable $\lambda 2200$ absorption dip.

ANALYSIS AND DISCUSSION

The orbital phase coverage of our nine IUE spectra presents the opportunity to analyze variations in line strength, continuum flux levels and interfacing with the theoretical predictions of available binary models of cataclysmic variables. Using all of our spectra, the first ultraviolet light curve of the system is shown in figure 3. Ultraviolet fluxes at $\lambda 1800$ and $\lambda 2400$ are plotted versus time. In the same figure, we display a Fine Error Sensor (FES) light curve. The light variations shown in both the UV and FES light curves are consistent with the photometric period found previously (ref. 2). The shapes are also similar, but the amplitudes of the variation in both light curves are larger while the mean optical light level is lower than previous photometric studies by about $0^m.5$ (ref. 2). In figure 5, we plot the continuum fluxes for TT Ari taken from the SWP 6278 and LWR 5446 exposures near maximum light. The UBV fluxes in figure 5 are from the photometry in reference 2 where the magnitudes were normalized to value of $V_{\max} = +11^m.90$ obtained from the FES measures. These were converted to absolute flux units with a calibration of Hayes (ref. 7). In the same figure we plot, for comparison, a $F_{\nu} \propto \nu^{1/3}$ flux distribution for a viscous steady state optically thick disk based upon local black body behavior, a model stellar atmosphere ($T_{\text{eff}} = 15,000$; $\log g = 4.5$) from Kurucz (ref. 8) and a steady state optically thick model accretion disk from the grid of Herter et al. (ref. 9) corresponding to a mass transfer rate $\dot{M} = 10^{-7} M_{\odot}/\text{yr}$; $i = 30^\circ$. It is apparent that the accretion disk fits are in rather large disagreement with the overall continuum. On the other hand, a Kurucz model atmosphere gives a reasonable fit to the data and implies an $T_{\text{eff}} \leq 20,000^\circ\text{K}$. The lines exhibit an interesting phase behavior in the short-wave region. Spectra SWP 6275 and 6278 are near the same relative orbital phase (i. e. maximum light) and have essentially the same line features. Exposure SWP 6277 was obtained near minimum light and reveals weaker overall absorption lines and stronger emission in C IV, which has the appearance of a P Cygni profile. Spectrum SWP 6276 occurs at a relative phase intermediate between SWP 6275 and 6278. Cowley et al. (ref. 1) also find phase dependent changes in their optical spectra which they interpret as being caused by the changing aspect of the hot spot on the accretion disk of the primary, arising from orbital motion. They attribute the observed optical light variations to the same model. However, the presence of the P Cygni C IV feature strongly suggests some type of mass outflow from the system.

Our ultraviolet spectra raise several new puzzles about the nature of TT Arietis

and related objects. (1) Why are current disk models in disagreement with our continuum fluxes? Are the disk models unrealistic or is there an accretion disk present at all? If the latter is the case, all of the phenomena associated with a disk (e.g., rapid flickering, hot spot, etc.) must be discarded. (2) Are the strong absorptions arising from the disk, the stellar component or possibly the hot spot? What is the significance of the apparent phase dependence of the CIV P Cygni profile? Is it arising from a stream, a spherically outflowing stellar wind or from a disk? A resolution of some of these puzzles may be possible with a detailed analysis of the line strengths and shapes as a function of orbital phase at both maximum and minimum light. Would coverage of 2 or more consecutive orbits over an extended interval reveal the same phase dependent behavior as reported here? (3) If the interpretation of Cowley et al. (ref. 1) is correct why does the system not exhibit dwarf nova type outbursts? A more detailed analysis of this interesting system will be forthcoming.

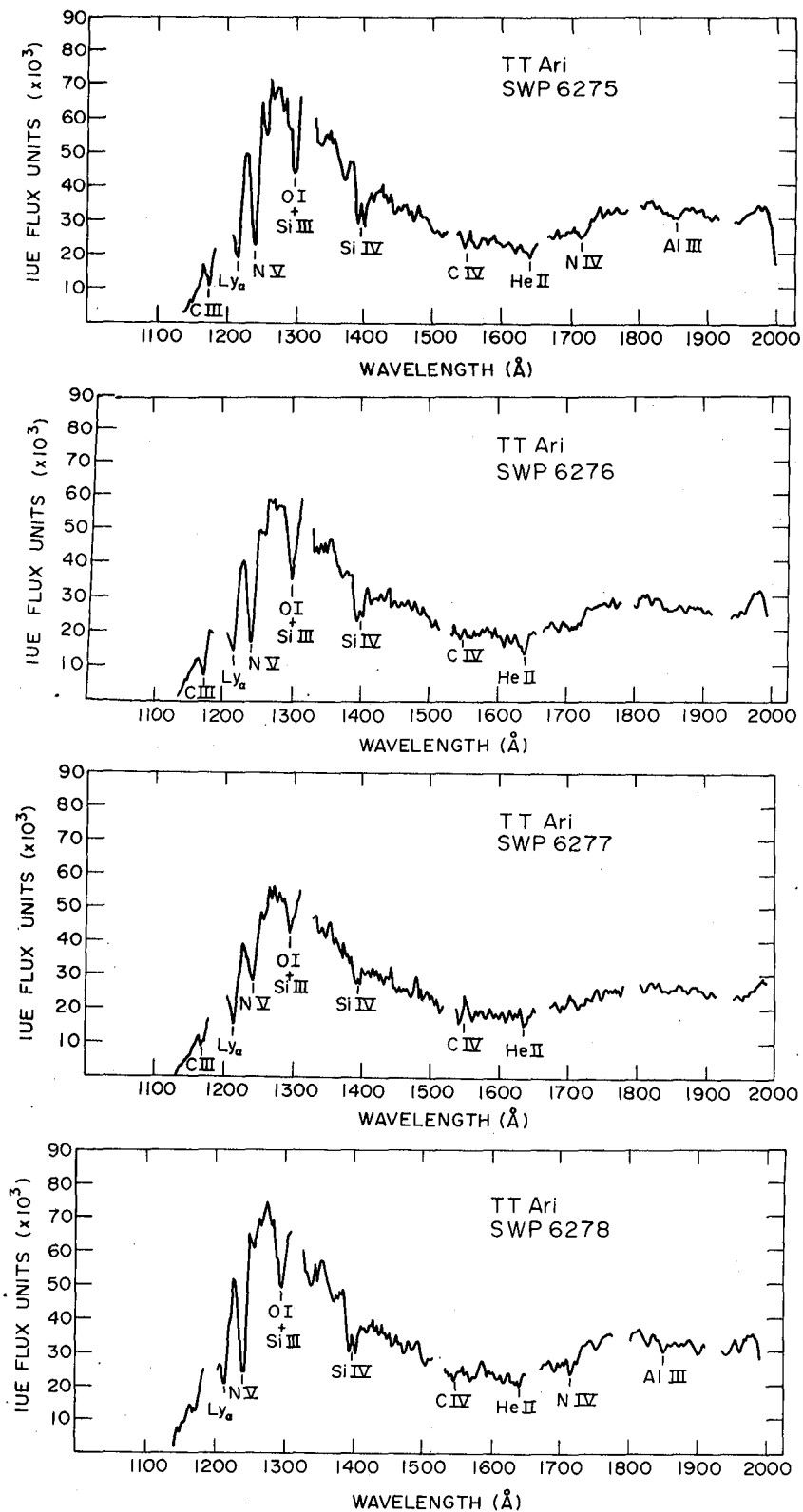
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TABLE I

IUE SPECTRA OF TT ARIETIS

Camera Number	Aperture	Exposure (min)	Time of Mid-Exposure AUG. 24.0 U. T. 1979
LWR 5445	Lg	15	24.4317
SWP 6275	Lg	10	24.4451
LWR 5446	Lg	8	24.4649
SWP 6276	Lg	9	24.4866
LWR 5447a	Lg	4	24.5051
LWR 5447	Sm	4	24.5266
SWP 6277	Lg	9	24.5363
LWR 5448	Lg	4	24.5558
SWP 6278	Lg	9	24.5786



Figures 1-4: IUE flux plots of TT Arietis as a function of relative orbital phase plotted in IUE flux units vs. wavelength expressed in \AA units.

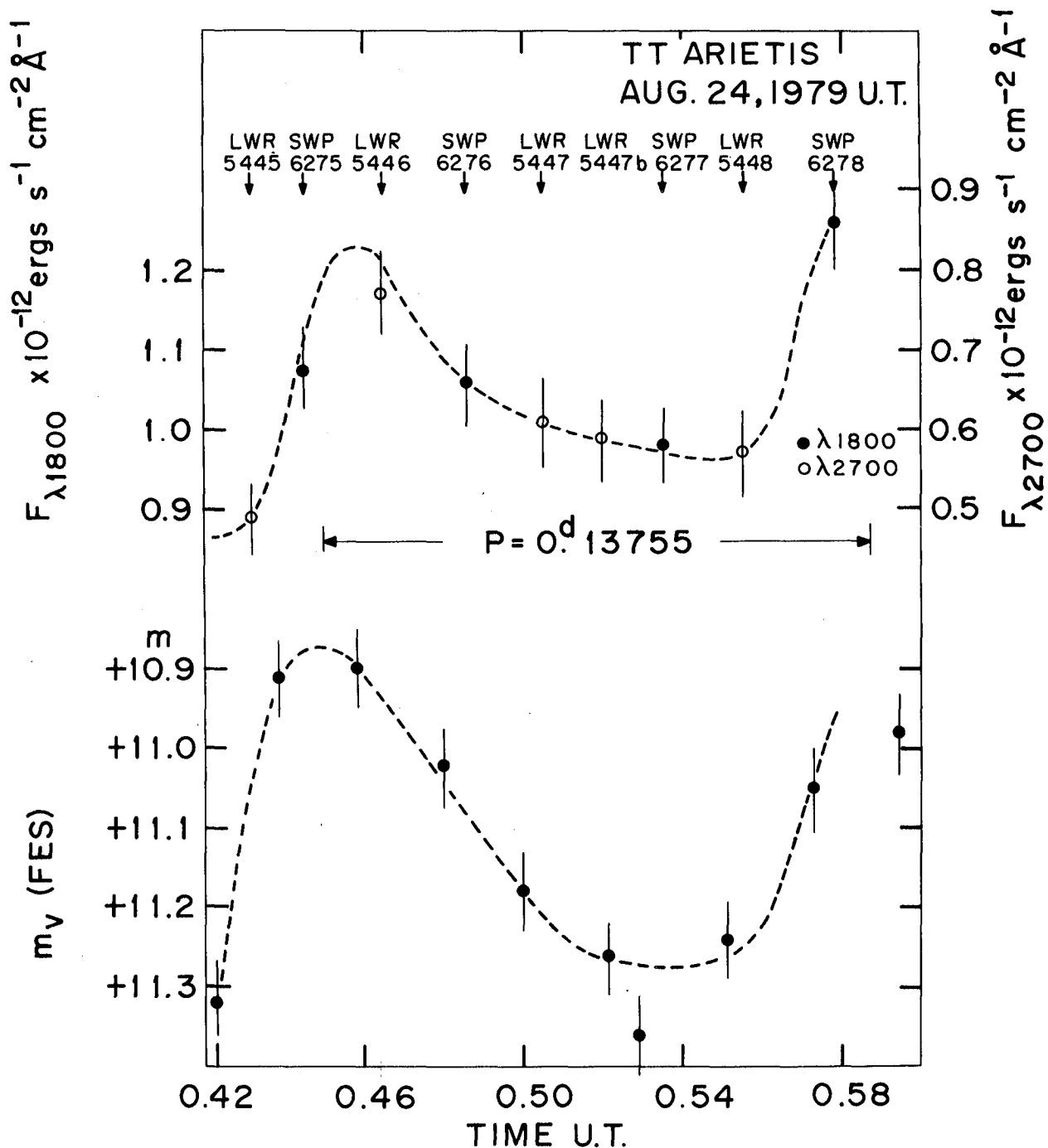


Figure 5:

Top panel of the figure shows a plot of the $\lambda 1800$ and $\lambda 2700$ UV fluxes obtained over 100 Å bandpasses. The $\lambda 1800$ and $\lambda 2700$ fluxes were shifted in the figure to match at minimum light near Aug. 24.54 U.T. 1979. The times at which the various IUE spectra were obtained are also indicated in the figure. The apparent visual magnitude obtained with the FES on the satellite are also shown.

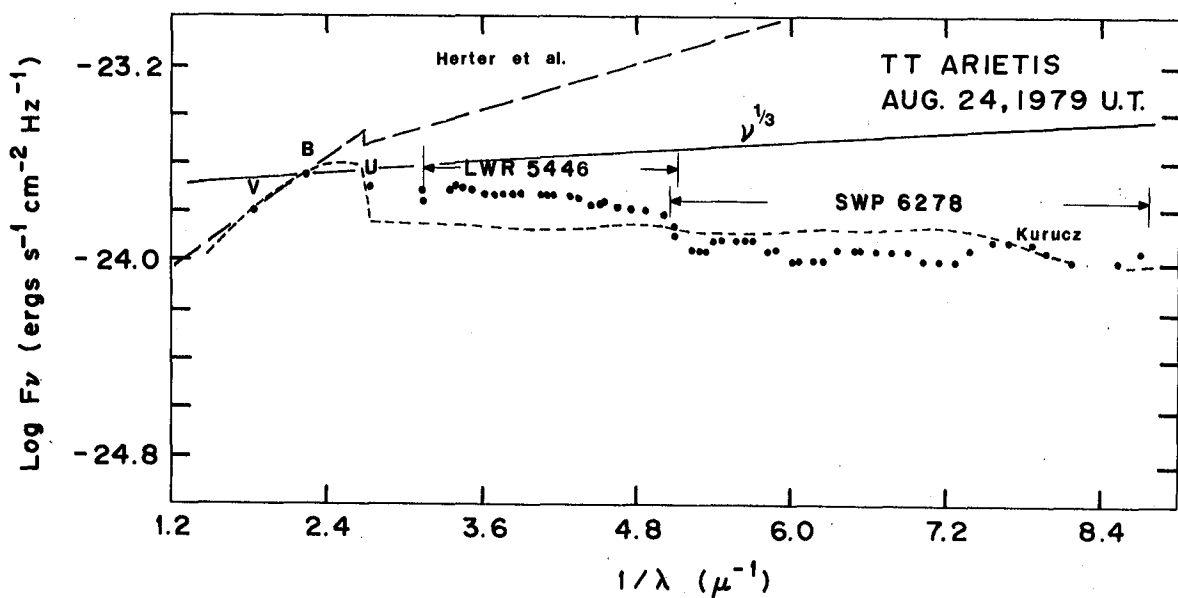


Figure 6:

Flux plot of $\log F_\nu$ vs. λ^{-1} . The small dash curve is a Kurucz model atmosphere for $T_{\text{eff}} = 16,000^\circ\text{K}$; $\log g = 4.5$, the large dash curve is a Herter et al. accretion disk model, ($\dot{M} = 10^{-7} M_\odot/\text{yr}$; $i = 30^\circ$) and the solid curve is $F_\nu \propto \nu^{1/3}$. Optical fluxes are labelled with corresponding bandpass designations.